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Keynote Paper

Cost of Industrial Product-Service Systems (IPS^2)

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Abstract

The motivation of this Keynote comes from the lack of research in estimating costs of an industrial product-service system (IPS^2). A competitive IPS^2 framework has been developed by Cranfield University for delivering sustainable customer value. This framework describes the capabilities of solution providers and the constraints involved in delivering IPS^2. The paper builds on this framework by considering cost at various stages of the life cycle. The framework will analyse the key drivers, the major issues and how the cost evolves from traditional pure product perspective to IPS^2 from the point of view of the customer and the solution provider. The obsolescence, uncertainty, supply chain and customer value areas are analysed in-depth because they are found to be the major drivers in IPS^2.

Keywords:
Industrial product-service systems, cost, uncertainty, obsolescence, supply chain

1 INTRODUCTION

The traditional view of manufacturing companies is focused on selling the physical product. Due to the ever increasing global competition as well as the demands for greater responsibility of the manufacturer for their products throughout the entire life-cycle, enterprises are forced to shift their business focus from designing and selling physical products only to offering integrated industrial Product-Service Systems (IPS^2). An IPS² is an integrated product and service offering that delivers value in use [1]. Such combined solutions continuously provide value to the customer and therefore represent an innovative strategy to not only fulfil client demands jointly but also to compete successfully on the global market [2]. The offering of IPS² with dynamic interdependency of products and services in the production area are transforming the traditional definition of organization into a new form of relationship between the customer and the providing company [3]. IPS² solutions are designed flexibly in regard to possible changes of individual customer needs and requirements during the use-phase [4]. New opportunities arise out of the provision of IPS². The interdependent bundle of products and services of the IPS² generates a greater value for the customer. Unlike the normal product offering with defined functionality the IPS² includes a greater variety of functions through integrated services and therefore a higher value. It is developed as an integrated solution by the original equipment manufacturers (OEMs) and thus the customer is normally not able to separate parts of the IPS² to get them from another supplier. And third the customization of the IPS² makes it difficult for the customer to compare it with another offered solution [5].

The evolution of IPS^2 is driven by the escalation of service economies in highly industrialised countries [6]. Services have an increased share within the manufacturing industry [7; 8]. The traditional boundary between manufacturing and services is becoming increasingly blurred. Traditional production oriented companies such as ABB, SKF, Volvo, Rolls-Royce, BAE Systems and many others are all moving towards delivering comprehensive solutions where services are becoming increasingly important [9,1]. According to Oliva and Kallenberg [10] management literature is almost unanimous in suggesting to product manufacturer to integrate services into their product offerings. They also argue that the literature is sparse in describing the challenges inherent in the IPS^2 offerings.

Baines et al., [1] have identified several key challenges of product service systems (PSS), synonymous to IPS^2, because services are inherently different from products. The transformation towards including a higher degree of services in the “product solution” has in some cases produced some managerial difficulties for companies [10]. As [1] point out companies need to be able to configure their products, technologies, operations and supply chain to support their value offering and there is little guidance in existing literature on how to achieve this. Shehab et al [11] reiterate this by stating that understanding specific transformational issues and how to overcome these is a principal future challenge for such systems. Hansen and Mowen [12] argue that traditional costing has emphasized on companies manufacturing physical products and virtually ignored costing of services. Cost assessment of such offerings remains a challenge and has not been addressed in literature. Some of whole life cycle cost literature focuses on assessing the maintenance or in-service costs [13; 14; 15]. But most of this literature is focused towards costing the service associated with stand-alone products. In most of these studies, services are viewed as “add-ons” to products and treated as mere features of the products. We believe it is of high interest studying potential problems with costing IPS^2 based on the fact that literature has stated that manufacturing are moving towards becoming more service focussed, but at the same time literature is rather limited in terms of discussing costing of integrated IPS^2.

Based on the discussion above, we decided to produce this keynote paper on cost assessment of IPS^2. This research builds on the competitive IPS^2 framework developed by Cranfield University researchers [16] as described in the next section. The research is based on studying the industry practice of life cycle costing of support service solutions across 5 availability contracts between UK MoD and four major OEMS in the defence industry and literature review. The study is performed over an 18 months period and is based on extensive face to face semi-structured interviews, workshops and document analysis. Experts from availability contract management, whole life cost estimating, bidding team, commercial groups, business development teams, customer and supplier are involved in the study.

Next this paper describes a costing framework for IPS^2 and maps the findings from an empirical study carried out on British defence contracts. The paper identifies the major drivers and issues of IPS^2 costs and shows how the cost evolves from traditional pure product perspective to IPS^2 from the point of view of the customer and the solution provider. The obsolescence, uncertainty, supply chain and customer value areas are analysed in-depth because they are found to be the major drivers in IPS^2 from both empirical research and literature.

2 A COMPETITIVE IPS^2 FRAMEWORK

There are different business models within an IPS^2 according to the level of integration of products and services, namely: Product oriented, Use oriented and Service oriented (Figure 1).

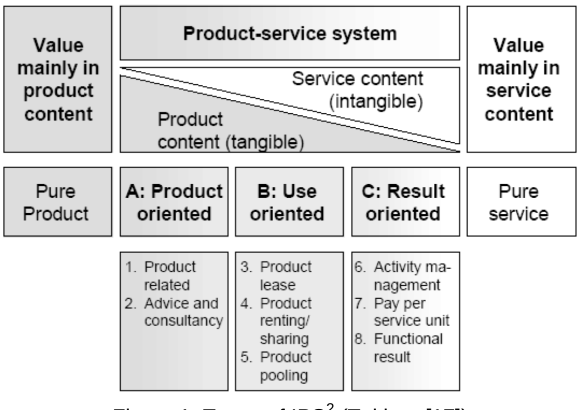

Figure 1: Types of IPS^2 (Tukker, [17])

After a thorough review of research available in the field of IPS^2 and related areas (PSS, industrial services, service management), a competitive framework is developed by Cranfield University researchers for sustainable customer value (Figure 2).

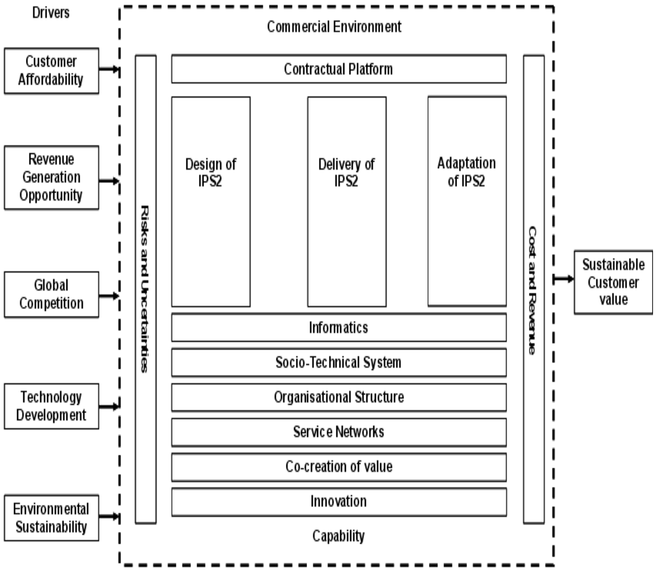

Figure 2: A Competitive IPS^2 Framework
(Roy and Cheruvu, [16])

Various drivers for this framework are identified as customer affordability, revenue generation opportunity, global competition, technology development and environmental sustainability. The framework consists of mainly three main aspects in broad sense for IPS^2 business, such as commercial environment, capabilities and three major aspects of IPS^2 life cycle. Commercial environment for IPS^2 is about influencing factors and elements in financial perspective of IPS^2 and consists of ‘risks and uncertainties’, ‘contractual platform’ and ‘cost and revenue’. In order to achieve a successful IPS^2 for sustainable customer value the solution provider should have various capabilities like, informatics (information technology, communication tools, knowledge data base etc), socio-technical system (integrated humans and technical systems), organisational structure, service networks, co-creation of value and innovation at all the stages of IPS^2 life cycle. Finally IPS^2 life cycle is identified by three main aspects such as design of IPS^2, delivery of IPS^2 and adaptation of IPS^2. The aim of this competitive framework is to depict various elements involved in IPS^2 and their co-ordination or interplay through out the life cycle in order to achieve profits for the solution provider and sustainable customer, a key success for any business.

Such a framework is lacking in contemporary literature though there have been a plethora of definitions of IPS^2. The key aspect of this framework is that, it highlights the multidimensional nature of IPS^2 and shows how the different drivers, environment and capabilities can evolve over life cycle. Such a framework helps in identifying the key costs over the life cycle of IPS^2 offerings.

3 COST PERSPECTIVES IN IPS^2

In this section the cost of IPS^2 is discussed from several different perspectives. First, based on the presented Competitive IPS^2 Framework, this section demonstrates a representation of costs in such systems. Secondly, the framework also takes a combined customer-supplier perspective in terms of ownership of the costs. Thirdly, the framework also demonstrates the key elements and drivers of cost generation within an IPS^2 context. The difference of these drivers of cost from traditional product centric transactions can be considered to be the service oriented nature of IPS^2 where intangible performance metrics drive costs. However, the degree of cost ownership varies depending on the IPS^2 business model, whether it be a product (i.e. add-on service for sold product), use (i.e. lease or rent product) or result (i.e. product output driven) oriented approach. The framework assumes product and result oriented business models as the two extremes of IPS^2 delivery. Furthermore, between the product and result oriented models, a transition in approaches can be considered as the service orientation becomes more complex in a result oriented context for the supplier. This is represented before in Figure 1. Finally, the cost framework also shows the costs for different stages of life cycle.

The entire cost framework is shown as a wagon wheel in Figure 3 where the IPS^2 cost elements are at the centre of the wheel. The key cost elements are recurring costs (RC) (e.g., labour, materials, machining costs, logistics and sub-contract costs), non-recurring costs (NRC) (equipment, facilities, capital goods, design development efforts), overheads (OH) (personnel, development of personnel, infrastructure, administration). The hidden costs and risk/uncertainty (R&U) are found to be crucial elements of IPS^2 costs and are discussed below.

Hidden Costs – One of the most important elements of IPS^2 cost are the hidden elements which include issues such as cost of relationship management, communication costs, cost of lack of detailed level data, cost of reverse logistics and flexibility of response, cost of cultural changes or change management which exist but cannot be quantified with traditional cost estimating methods. The prominence of the hidden cost elements becomes more explicit due to the immaterial character of services. Perhaps the most important hidden costs are not technology-related and consist of people costs involving customer relationship management and value.

Risks and Uncertainties – The risks and uncertainties from multiple sources form another important part of IPS^2 costs. Uncertainty derives from lack of information or knowledge and causes events to be known imprecisely or unknown. As well as being a source of negative outcomes, it also has the ability to create opportunities. In contrast, risk only covers threats, where it is possible to assign probabilities to outcomes. All these elements influence the major cost drivers at different phases of the competitive IPS^2 life cycle and also get influenced by the wider business drivers mentioned in the competitive IPS^2 framework.

The major cost drivers within an IPS^2 system can be considered to be within the different phases of the IPS^2 life cycle shown in Figure 3:

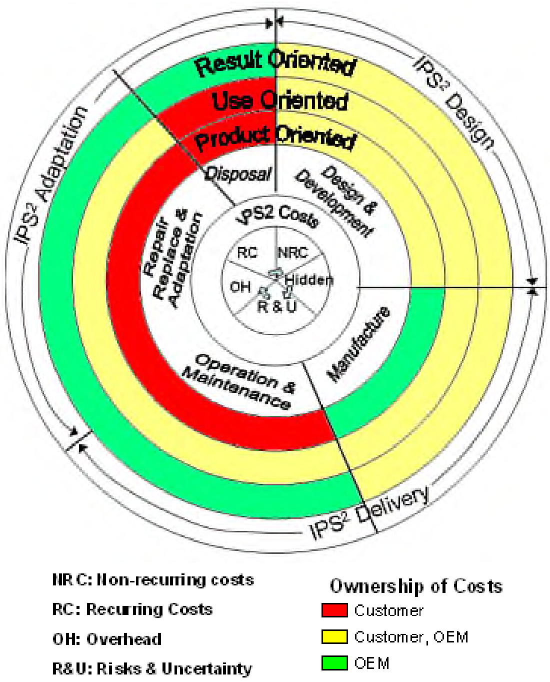

Figure 3: IPS^2 Cost – Conceptual Wagon-wheel

1. *IPS^2 Design Phase:* This includes the cost of equipment and service purchased. At this stage, analysts appraise a variety of projects by discounting all future costs [In a traditional perspective, this stage considers performance, effectiveness, reliability, maintainability, supportability, quality, recyclability, as well as initial cost [14]. This phase involves the design costs relating to service and product design (the key drivers are depicted in Figure 4). Figure 3 shows the different ownership of these costs through different colour codes. Customer bears majority of costs in product oriented business model and supplier bears more share in result oriented model.
2. *IPS^2 Delivery Phase:* This will involve manufacturing and operations phases in IPS^2. In use and result oriented models, the costs associated with manufacturing are responsibility of both customers and suppliers. Since in both these models, customers play an active role during the service "manufacturing" process. Services are created and instantly consumed by the customer. Companies have to make sure they have sufficient resources at their disposal to carry out the service process when it is requested by the customer. The supplier takes the ownership of manufacturing costs in product oriented models. With the customer transferring service responsibilities to the supplier the operations and maintenance costs are borne solely by the suppliers in result oriented models and customers in product oriented models. These include major cost drivers such as supply chain, logistics, energy usage, labour costs.
3. *IPS^2 Adaptation Phase:* Due to differing needs of customers, IPS^2 processes need to adapt differently each time for new upgrades, repairs or disposals. Dispatching capable employees is a crucial prerequisite for providing services in sufficient quality in this phase. Performance becomes a key criterion for the use and result oriented models. For instance, in a use oriented approach the customer may require a pre-defined availability level, which the supplier needs to

Design and Development	Manufacturing	Operation and maintenance	Repair, Replace and Adaptation	Disposal / recycle
•Structure	•Material	•Usage	•Unplanned repairs	•Disposal Strategies
•Fixtures and fittings	•Labour Rates	•Energy	•Varied demands	
•Specifications	•Machine Rates	•Utilities	•Periodic repairs	
•Testing	•Manufacturing process	•Taxes	•Mean time repair	
•Training	•Tooling	•Insurance	•Unit spares cost	
•Initial spares	•Supply Chain & Logistics	•Remote sensing	•Spare parts	
•Performance requirements	•Infrastructure	•Cleaning	•Training	
•Maintenance Cycles		•Training	•Technology obsolescence	
•Supply Chain Structure		•Inspection	•Infrastructure	
•Service Breakdown		•Supply Chain		
		•Inventory Policy		
		•Maintenance Policy		
		•Mean time between failures		

Figure 4: IPS^2 Cost Drivers

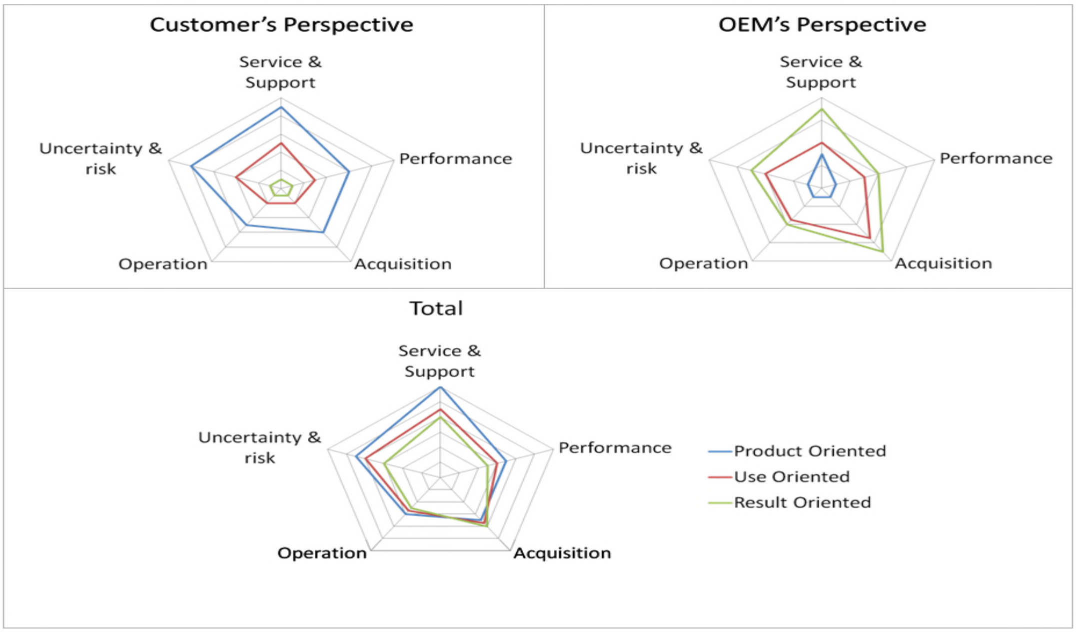

Figure 5: Evolution of Cost for different categories of IPS^2

sustain over a given amount of period. To be able achieve this, some adaptations to the infrastructure, while creating new costs such as monitoring, have become necessary. Technology Obsolescence is a key driver found in this phase.

Along these lines, the influence of uncertainty and risk on cost drivers has been acknowledged to be the source of complexity in achieving the ultimate goal of continuous co-creation of value between the customer and the supplier. The framework suggests that by considering the influence of uncertainties and risks over the cost drivers for each type of IPS^2 business model, the sustainability of such systems can be managed, while enabling the co-creation of value deriving from the IPS^2 system. The cost drivers for different phases described above are identified in Figure 4 by studying the industry practice of life cycle costing of support service solutions across 5 availability contracts between UK MoD and two organisations in defence industry.

The costs incurred on IPS^2 evolve as the business model moves from 'Product oriented' towards 'Result oriented'. In general the costs are shifted from the customer to the OEM. This is represented by means of the major cost drivers in Figure 5. The first two spider diagrams show how the costs evolve from the customer and the OEM's point of view respectively. The third one shows how the total, the summation of costs for the supplier and the customer, decreases when moving from 'Product oriented' towards 'Result oriented' business model. The evolution of each cost driver is explained as follows:

- Acquisition: It increases due to the additional equipment required (e.g. monitoring) for the optimization of the support.
- Service and Support: It decreases because it is managed by the supplier in a more cost-effective way.
- Risk and Uncertainty: It decreases because it is better managed, and hence reduced, by the supplier.
- Operation: It decreases because the OEM is able to operate the system in a more cost-effective way.
- Performance: It decreases because the likelihood of having penalties (or loss of revenue) due to poor performance decreases.

The next sections detail some of the major cost drivers and major issues surrounding IPS^2 costs. This paper discusses uncertainty, obsolescence and supply chain as major influencers of IPS^2 costs. The paper discusses customer value as an important hidden cost in IPS^2 where the value of services is reflected as a cost even if no cash outlay is involved.

4 INFLUENCE OF UNCERTAINTY ON IPS^2 COSTS

Uncertainty refers to things that are not known, or known only imprecisely [18]. Although, many uncertainties related to cost are measurable, some are not due to the unpredictable nature of the future. Furthermore, handling of uncertainty depends on the level of information and knowledge that is available at a given time [19]. Taking an IPS^2 approach causes a shift in the types of uncertainties that are relevant to the supplier and the customer. The main sources of this change can be summarised as [20]:

- Agreeing performance centric contracts (i.e. availability) have created additional complexities necessitating consideration of uncertainties in a bundled and concurrent manner for both suppliers and customers
- Offering services that suppliers have relatively little experience in (i.e. provision of training through simulation devises)
- Availability contracts also demand 'left shift' of the point-in-time at which some uncertainties are addressed yet the information needed to resolve some of them may not be available during bidding

In an IPS^2 context the key types of uncertainty derives from commercial aspects (i.e. customer affordability or supplier profitability), service delivery by considering the capability of the supplier (i.e. development in: use of technology, processes, business knowledge, staff performance), equipment (i.e. failure, customer misuse or inadequate support; faulty equipment), contractual requirement changes, macro factors (i.e. economy, government intervention, competition, safety and environmental burden) and the cost estimation process itself.

To be able to understand the changes in the types of uncertainties, when taking on an IPS^2 approach, it is necessary to consider the relevant processes for each type of business model. Furthermore, it is also necessary to understand the required knowledge to be able to deliver an IPS^2, in order to see the potentially new sources of uncertainty.

Based on Figure 6, the potential uncertainties are considered in relation to costs that may get influenced, within the three IPS^2 business models. The figure describes the reduction in system level uncertainty when moving from a product oriented approach to use and result, respectively. This is particularly driven by the transfer of risks and uncertainties from the customer to the supplier, who can handle equipment related issues better due to its advantage deriving from its experience and knowledge. Along with this, in a parallel manner system level costs also reduce.

In conclusion, research in uncertainty for cost estimation within an IPS^2 context needs to better understand uncertainties that derive from the service supply chain. This is mainly because an IPS^2 approach promotes further reliance on suppliers. Furthermore, it will also be beneficial to study appropriate modelling approaches for particular types of uncertainty that develop in service delivery.

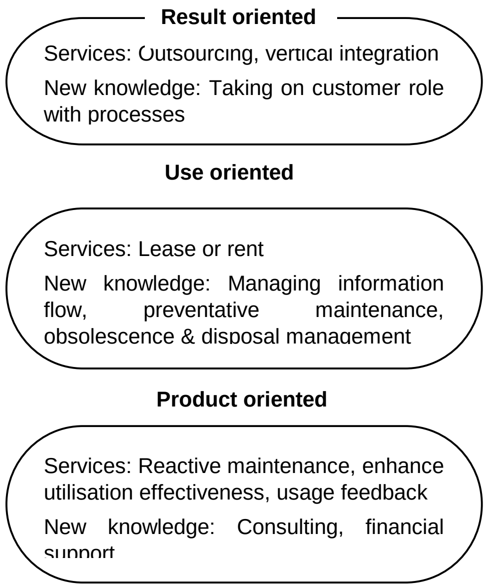

Figure 6: Offered services and required knowledge for IPS^2 business models

5 THE EVOLUTION OF OBSOLESCENCE COSTS ACROSS IPS^2

In general IPS^2 are contracted for long periods of time. However, as the technology is changing at an increasing rate, the life-cycle of the electronic components is decreasing, and hence they become obsolete before the end of life of the system they are built in [21; 22; 23; 24; 25; 26]. Therefore, if any component becomes obsolete, it is necessary to tackle the obsolescence issue in order to continue supporting the system.

Obsolescence has become one of the main cost drivers during the in-service and support phase of IPS^2 [27]. This cost is especially significant for legacy equipment as most of the electronic components are reaching the end of life [21].

Obsolescence is an unavoidable problem. Therefore, it needs to be managed in order to mitigate its impact on the systems, and ultimately on costs. Discussions with many industrial experts in obsolescence allow concluding that the IPS^2 provider (OEM) is in a better position than the customer due to the following reasons:

- Better knowledge about the Bill of Materials (BoM), subsystems and assemblies and interaction of components within the system.
- Direct link with the manufacturers and suppliers of components.
- In many cases, they have the Design Authority (DA), which allows them to make any modification to the system design required to solve an obsolescence issue.

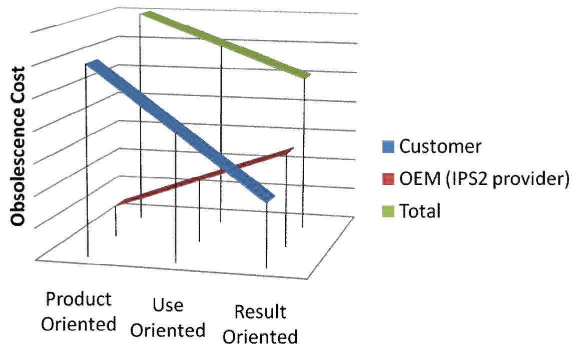

Figure 7: Evolution of Obsolescence Cost for different categories of IPS^2

The evolution of a business model from 'Product oriented' through to 'Result oriented' implies a higher degree of involvement of the OEM in the in-service and support of the system. Figure 7 represents the conclusion drawn from several interviews with obsolescence experts from the defence sector (both customer and OEM perspectives). It shows how moving towards 'Result oriented' type contracts, the customer is passing on costs to the OEM, who takes responsibility of managing obsolescence. Nevertheless, the total obsolescence cost, derived from managing and resolving obsolescence issues, is reduced when the OEM is in charge of managing obsolescence. The reason for this is that the OEM is in a better position to manage obsolescence proactively, and hence, it can be done in a more cost-effective way.

6 SUPPLY CHAIN FOR IPS^2

A *supply chain* is a network of facilities and distribution options that performs the functions of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of these finished products to customers. This traditional supply chain structure fits perfectly in product based model but for delivering of IPS² some additional characteristics are necessary. A service cannot be stored because of immaterial character. Furthermore services are offered and consumed simultaneously. Quality assurance is especially difficult, because there can be no inspection at the end of the creation process due to simultaneous consumption. Services cannot be produced in advance and hence service capacity must be managed, because it is inescapably lost if unused. In addition to these service characteristics the IPS² characteristics have to be considered as well. The longer lasting responsibility for solutions and the willingness to react on changing demands of the customer leads to high demands for the IPS² supply chain. Extant literature on cost estimation involve the provision of traditional reactive services and focus on ensuring the proper functioning of the equipment consisting of maintenance, repair and overhaul, spares provisioning, technical publications and technical support [28]. Efficient usage of the existing capacity is more important than the best fulfilment of the desired solution of the customer [3]. An agile IPS² network has to be developed that can be changed dynamically with varying customer demands.

From our study on defence contracts, several key supply chain issues for IPS² network costs arise. First of them all is reverse logistics related costs incurred due to shipping parts which are not faulty for repairs due to lack of monitoring, cultural backlashes (inheriting "if in doubt send back for repairs" supply chain culture). Secondly, lack of visibility of parts within supply chains result in large procurement, inventory and obsolescence costs. Third, inaccuracy of predicting customer usage results in poor resource planning and hence additional costs. Fourth, the scale of availability contracts means 'in-house' is not an option, 'collaboration' is mandated. Good communication with the supply base can address scale to some extent through being consistent and coherent. However findings suggest few firms attempt to manage beyond one or two tiers. Fifth, at face value there is very little incentive in service support business for the majority of suppliers. Suppliers are required to continue to repair items but with no access to the customer. It is particularly difficult to incentivise an incumbent supplier, when i) the work it is not core to their business; ii) the supplier is not interested in military air business, and iii) may not have won work on future projects. In addition, suppliers sometimes do not have the resources to spend on adapting to new circumstances. Sixth and finally, first or second tier suppliers account for the majority of supply chain cost, playing key roles in sub systems, technical upgrades, repairs and obsolescence management; but they are often in ambiguous roles in relation to OEM in service support. They are also potential competitors in service support by combining their major design authority status and associated technical capabilities with cost effective logistical capabilities.

7 HIDDEN COSTS OF CUSTOMER VALUE IN IPS^2

Services as such are not patentable. Furthermore, it is difficult for customers to assess the value of the service in advance of the service process. The risk issues identified in current cost estimating practices are mainly concerned with equipment related risks with no consideration for customer value. The need to establish a direct link between the costs a firm sustains to deliver its offering and the immediate effects on the customer's perceptions and attitudes has been highlighted by a few scholars in accounting research [29; 30; 31]. As the demand increases for companies to become customer-centric, an understanding of the relationship between customer satisfaction and costs becomes critical, in order to trace the roots of profitability at the customer level [32]. Recent developments in service cost literature allow for a stronger focus on the customer, but there are no studies concentrating explicitly on the relationship between cost and value or the risks arising thereof.

The findings from the defence industry study provides some interesting issues for considering value related risks in IPS^2 costs [33]. First, the change from the traditional way of doing business to IPS^2 has caused discomfort in terms of understanding the activities involved. While clear performance indicators relate to availability, many in the companies are aware that the performance is unachievable without the cooperation of the customer. The impact of costing these within the contracts is not available in practice or literature as these cannot be captured through financial figures. In traditional business models, the delivery of specific activities (e.g. repair) or products are directly chargeable and the value to the customer is often directly attributable to what activities are rendered by the company. However, under IPS^2 type business models (use and result oriented) the performance assessed is the output of the company's *collective* efforts and activities, the link between customer value and the activities of the company becomes fuzzier. The defence industry's activities and structure are mostly product-centric i.e. most of the activities, solutions and models are focused around the tangible aspects of the service i.e. the *equipment* capabilities (that are to be maintained, repaired, overhauled or made obsolete) that contribute to the value; without much focus on the behavioural and *human capabilities* that also contribute towards delivering value. The focus of the organizations on tangible aspects of the service may result in the organization while estimating the costs, overlooking the effectiveness, adequacy and completeness of the service design that brings in human and equipment capabilities that deliver value to the customer. This product-centric approach to cost estimation may also limit the ability of the organization to achieve compliance and efficiency gains when delivering the service on through both equipment and human resources. On the basis of these major challenges, the companies therefore may find themselves exposed to customer-focused risks that threaten the companies' *capability towards delivering service value* that is replicable, consistent and scalable across future service projects. The customer-focused hidden cost estimation remains an area for future research.

8 CONCLUSIONS

In this paper we demonstrated that the creation and provision of industrial product-service packages is a crucial issue in today's economy. Even so, representing costs of industrial product-service systems with conceptual models is lacking sound methodological support. In this paper, we described the research work Cranfield University is leading in terms of developing a competitive framework of IPS^2. This paper builds on this framework and presents a cost framework representing the different cost elements, drivers across different phases of IPS^2 life cycle and differential ownership of costs by supplier and customer. The driver identification is backed by empirical case based research at UK defence industries. This paper reports perspectives for research in several dimensions.

a) Although the framework shows the distribution of costs between supplier and customer conceptually across different phases of IPS^2 life cycle but the exact proportion of these ownerships remains a challenging future research question. Also companies may start asking questions on the right business model to operate with optimum costs in the face of future competition. The right product/service mix design based on total costs can remain a worthwhile research question for future.

b) The research on the effects of customer-perceived risks in cost estimates of IPS^2 service contract can be another fruitful research area. Then inclusion of human behavioural aspects into the cost models to make them more service focused remains a potential research area for future.

c) Another area for future research is to study the most effective supply chain structure for IPS^2 offerings.

d) Modelling uncertainties and obsolescence costs of such contracts remains an area for further research

Therefore, the concepts presented in this paper act as a starting point to develop a tighter methodological support for conceptual models, that will be evaluated more thoroughly in a variety of real-life industrial product-service systems.

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